CLMPTO

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1.   A device for calculating diffraction efficiencies of a diffraction lens divided into a plurality of regions, each region comprising at least one grating ring,   the device comprising:

a first memory for storing information about diffraction efficiencies of said regions;

a second memory for storing information about weights corresponding to said regions;   and

a first processor for retrieving information from said first and said second memories, and calculating diffraction efficiencies of the entire diffraction lens using the formula

(1) $E_j = \sum_{m=1}^{M} W_m \eta_{mj}$

wherein:

j :   integer indicating the order of diffraction light

E_j :   diffraction efficiency for j–th order diffraction light of the diffraction lens

M :   positive integer (M > 1) indicating the number of regions for which the diffraction efficiency is calculated

m :   index of the region for which the diffraction efficiency is calculated

η_{mj} :   diffraction efficiency for the j–th order diffraction light of the m–th region (stored in the first memory)

W_m :   weight for the m–th region   (stored in the second memory means).

2.   The device according to Claim 1, further comprising:

a third memory for storing information about a relief cross–section shape of the diffraction lens;

a fourth memory for storing information about a wavelength of a light source;

a fifth memory for storing information about a refractive index of a material of the diffraction lens at said wavelength;

a second processor for retrieving information from said third, fourth

and fifth memories, and calculating diffraction efficiencies of said regions of the diffraction lens; and

a first repeating means for operating said second processor for a number of times that is equal to the number of said regions;

wherein the diffraction efficiencies η_{mj} stored in said first memory are calculated using said third, fourth and fifth memories, said second processor, and said first repeating means.

3.   The device according to Claim 1, wherein each grating ring of the diffraction lens corresponds to one of said regions.

4.   The device according to Claim 2, wherein said second processor performs a calculation using a Fourier transformation.

5.   The device according to Claim 1, further comprising a calculating means for calculating the weights stored in said second memory using information about the diffraction lens.

6.   The device according to Claim 1, further comprising:

a sixth memory for storing information about surface areas of said regions of the diffraction lens,   and

a third processor for retrieving information from said sixth memory, and calculating weights using the formula

(2) $$W_m = \frac{S_m}{\sum_{i=1}^{M} S_i}$$

wherein:

S_m : surface area of the m–th region

W_m : weight of the m–th region

M : number of regions into which the lens is divided

m : index counting the regions into which the lens is divided

i : integer   ,

wherein the weights corresponding to the regions stored in said second memory are calculated using said sixth memory and said third

processor.

7.   The device according to Claim 1, further comprising:

a seventh memory for storing information about radii of the grating rings of the diffraction lens;   and

a third processor for retrieving information from said seventh memory, and calculating weights using the formulas

(3) $W_1 = \dfrac{R_1^{\,2}}{R_M^{\,2}}$ and

(4) $W_m = \dfrac{R_m^{\,2} - R_{m-1}^{\,2}}{R_M^{\,2}}$ (m > 1)

wherein:

R_m : m–th grating ring radius counted from the center of the lens

W_m : weight of the m–th grating ring

M : number of grating rings

m : index counting the grating rings from the center of the lens

wherein the weights corresponding to the regions stored in said second memory are calculated using said seventh memory and said third processor.

8.   The device according to Claim 1, further comprising:

a seventh memory for storing information about radii of the grating rings of the diffraction lens;

an eighth memory for storing information about an intensity distribution for a light beam that is incident on the diffraction lens;   and

a third processor for retrieving information from said seventh and eighth memories and calculating the weights so that they are substantially proportional to the light intensity of the light that is incident on the corresponding grating ring of the diffraction lens;

wherein the weights corresponding to the regions stored in said second memory are calculated using said seventh and eighth memories and said third processor.

9.   The device according to Claim 2, further comprising a calculating means for calculating the cross–section shape of the diffraction lens stored in the third memory.

10.   The device according to Claim 2, further comprising:

a ninth memory for storing information about a relief profile design for the diffraction lens;

a tenth memory for storing information about a processing bit that is used for cutting the diffraction lens or cutting a die for forming the diffraction lens;

a fourth processor for retrieving information from said ninth and tenth memories, and calculating a relief profile of a diffraction lens that was cut with the processing bit or a relief profile of a diffraction lens formed using a die that was cut with the processing bit;   and

a second repeating means for repeatedly operating said fourth processor;

wherein the cross–section shape of the diffraction lens stored in said third memory is calculated using said ninth and said tenth memories, said fourth processor, and said second repeating means.

11.   The device according to Claim 2, further comprising:

a ninth memory for storing information about a relief profile design for the diffraction lens;

a tenth memory for storing information about a processing bit that is used for cutting the diffraction lens or cutting a die for forming the diffraction lens;

an eleventh memory for storing information about feed speed of said processing bit;

a fourth processor for retrieving information from said ninth, tenth, and eleventh memories, and calculating a relief profile of a diffraction lens that was cut with the processing bit or a relief profile of a diffraction lens formed using a die that was cut with the processing bit;   and

a fourth processor for retrieving information from said ninth, tenth, and eleventh memories, and calculating a relief profile of a diffraction lens that was cut with the processing bit or a relief profile of a diffraction lens formed using a die that was cut with the processing bit;   and

a second repeating means for repeatedly operating said fourth processor;

wherein the cross–section shape of the diffraction lens stored in said third memory is calculated using said ninth, tenth and eleventh

memories, said fourth processor, and said second repeating means.

12.   A device for calculating diffraction efficiencies of a diffraction lens divided into a plurality of regions, each region comprising at least one grating ring,   the diffraction efficiencies corresponding to a plurality of wavelengths, and the device comprising:

a first memory for storing information about diffraction efficiencies of said regions at the plurality of wavelengths;

a second memory for storing information about weights corresponding to said regions;

a third memory for storing information about a relief cross-section shape of the diffraction lens;

a fourth memory for storing information about the plurality of wavelengths;

a fifth memory for storing information about refractive indices of a material of the diffraction lens at said wavelengths;

a fourth processor for calculating a relief cross-section shape of the diffraction lens stored in said third memory;

a second processor for retrieving information from said third, fourth and fifth memories, and calculating therefrom diffraction efficiencies of said regions at said plurality of wavelengths stored in said first memory;

a third repeating means for operating said second processor for a number of times that is equal to the number of said wavelengths;

a fourth repeating means for operating said third repeating means for a number of times that is equal to the number of said regions;   and

a first processor for retrieving information from said first and said second memory, and calculating diffraction efficiencies of the entire diffraction lens using the formula

(5) $E_{jl} = \sum_{m=1}^{M} W_m \eta_{mjl}$

wherein:

  j : integer indicating the order of diffraction light

  1 : index of the wavelengths

  E_{jl} : diffraction efficiency for j–th order diffraction light of the diffraction lens at the l–th wavelength

  M : positive integer (M > 1) indicating the number of regions for which the diffraction efficiency is calculated

  m : index of the region for which the diffraction efficiency is calculated

  W_m : weight for the m–th region

  η_{mjl} : diffraction efficiency for the j–th order diffraction light of the m–th region at the l–th wavelength

Cancelled claims 13-14

15. (amended) An apparatus for designing diffraction lenses, comprising:

an input for entering lens design data; and

a processor for calculating optical properties and diffraction efficiencies of the diffraction lens obtained on the basis of said design data;

wherein the processor for calculating the diffraction efficiencies is a device for calculating diffraction efficiencies according to Claim 12.

16.   The apparatus according to Claim 15, wherein said design data comprises initial data and correction data, for correcting initial data.

17.   A diffraction lens designed using the apparatus according to Claim 15.

18.   A method for calculating diffraction efficiencies of a diffraction lens divided into a plurality of regions, each region comprising at least one grating ring,   the method comprising:

    a first memory step of storing information about diffraction efficiencies of said regions;

    a second memory step of storing information about weights corresponding to said regions;   and

    a first processing step of retrieving information stored in said first and said second memory step, and calculating diffraction efficiencies of the entire diffraction lens using the formula

(1) $$E_j = \sum_{m=1}^{M} W_m \eta_{mj}$$

    wherein:

j :   integer indicating the order of diffraction light

E_j : diffraction efficiency for j–th order diffraction light of the diffraction lens

M : positive integer ($M > 1$) indicating the number of regions for which the diffraction efficiency is calculated

m : index of the region for which the diffraction efficiency is calculated

η_{mj} : diffraction efficiency for the j–th order diffraction light of the m–th region (stored in the first memory step)

W_m : weight for the m–th region   (stored in the second memory

step).

19.   The method according to Claim 18, further comprising:

a third memory step of storing information about a relief cross-section shape of the diffraction lens;

a fourth memory step of storing information about a wavelength of a light source;

a fifth memory step of storing information about a refractive index of a material of the diffraction lens at said wavelength;

a second processing step of retrieving information stored in said third, fourth and fifth memory step, and calculating diffraction efficiencies of said regions of the diffraction lens;

a first repeating step of repeating said second processing step for a number of times that is equal to the number of said regions;

wherein the diffraction efficiencies η_{mj} stored in said first memory step are calculated using said third, fourth and fifth memory step, said second processing step, and said first repeating step.

20.   The method according to Claim 18, wherein each grating ring of the diffraction lens corresponds to one of said regions.

21.   The method according to Claim 19, wherein said second processing step includes a calculation using a Fourier transformation.

22.   The method according to Claim 18, further comprising a calculating step of calculating the weights stored in said second memory step using information about the diffraction lens.

23.   The method according to Claim 18, further comprising:

a sixth memory step of storing information about surface areas of said regions of the diffraction lens,   and

a third processing step of retrieving information stored in said sixth memory step, and calculating weights using the formula

(2)　　　$$W_m = \frac{S_m}{\sum_{i=1}^{M} S_i}$$

wherein:

S_m : surface area of the m–th region

W_m : weight of the m–th region

M : number of regions into which the lens is divided

m : index counting the regions into which the lens is divided

i : integer   ,

wherein the weights corresponding to the regions stored in said second memory step are calculated using said sixth memory step and said third processing step.

24.   The method according to Claim 18, further comprising:

a seventh memory step for storing information about radii of the grating rings of the diffraction lens;   and

a third processing step for retrieving information stored in said seventh memory step, and calculating weights using the formulas

(3) $W_1 = \dfrac{R_1^{\,2}}{R_M^{\,2}}$ and

(4) $W_m = \dfrac{R_m^{\,2} - R_{m-1}^{\,2}}{R_M^{\,2}}$ (m > 1)

wherein:

R_m : m–th grating ring radius counted from the center of the lens

W_m : weight of the m–th grating ring

M : number of grating rings

m : index counting the grating rings from the center of the lens

wherein the weights corresponding to the regions stored in said second memory step are calculated using said seventh memory step and said third processing step.

25.   The method according to Claim 18, further comprising:

a seventh memory step of storing information about radii of the grating rings of the diffraction lens;

an eighth memory step of storing information about an intensity distribution for a light beam that is incident on the diffraction lens;   and

a third processing step of retrieving information stored in said

seventh and eighth memory step and calculating the weights so that they are substantially proportional to the light intensity of the light that is incident on the corresponding grating ring of the diffraction lens;

wherein the weights corresponding to the regions stored in said second memory step are calculated using said seventh and eighth memory step and said third processing step.

26.   The method according to Claim 19, further comprising a calculating step of calculating the cross-section shape of the diffraction lens stored in the third memory step.

27.   The method according to Claim 19, further comprising:

a ninth memory step of storing information about a relief profile design for the diffraction lens;

a tenth memory step of storing information about a processing bit that is used for cutting the diffraction lens or cutting a die for forming the diffraction lens;

a fourth processing step of retrieving information stored in said ninth and tenth memory step, and calculating a relief profile of a diffraction lens that was cut with the processing bit or a relief profile of a diffraction lens formed using a die that was cut with the processing bit; and

a second repeating step of repeating said fourth processing step;

wherein the cross-section shape of the diffraction lens stored in said third memory step is calculated using said ninth and said tenth memory step, said fourth processing step, and said second repeating step.

28.   The method according to Claim 19, further comprising:

a ninth memory step of storing information about a relief profile design for the diffraction lens;

a tenth memory step of storing information about a processing bit that is used for cutting the diffraction lens or cutting a die for forming the diffraction lens;

an eleventh memory step of storing information about feed speed of said processing bit;

a fourth processing step of retrieving information stored in said ninth, tenth, and eleventh memory step, and calculating a relief profile of a diffraction lens that was cut with the processing bit or a relief profile of a

diffraction lens formed using a die that was cut with the processing bit; and

a second repeating step of repeating said fourth processing step;

wherein the cross-section shape of the diffraction lens stored in said third memory step is calculated using said ninth, tenth and eleventh memory step, said fourth processing step, and said second repeating step.

29.   A method for calculating diffraction efficiencies of a diffraction lens divided into a plurality of regions, each region comprising at least one grating ring, the diffraction efficiencies corresponding to a plurality of wavelengths, and the method comprising:

a first memory step of storing information about diffraction efficiencies of said regions at the plurality of wavelengths;

a second memory step of storing information about weights corresponding to said regions;

a third memory step of storing information about a relief cross-section shape of the diffraction lens;

a fourth memory step of storing information about the plurality of wavelengths;

a fifth memory step of storing information about refractive indices of a material of the diffraction lens at said wavelengths;

a fourth processing step of calculating a relief cross-section shape of the diffraction lens stored in said third memory step;

a second processing step of retrieving information stored in said third, fourth and fifth memory step, and calculating therefrom diffraction efficiencies of said regions at said plurality of wavelengths stored in said first memory step;

a third repeating step of repeating said second processing step for a number of times that is equal to the number of said wavelengths;

a fourth repeating step of repeating said third repeating step for a number of times that is equal to the number of said regions;   and

a first processing step of retrieving information stored in said first and said second memory step, and calculating diffraction efficiencies of the entire diffraction lens using the formula

(5) $E_{jl} = \sum_{m=1}^{M} W_m \eta_{mjl}$

wherein:

j :   integer indicating the order of diffraction light

l :   index of the wavelengths

E_{jl} : diffraction efficiency for j-th order diffraction light of the diffraction lens at the l-th wavelength

M : positive integer (M > 1) indicating the number of regions for which the diffraction efficiency is calculated

m : index of the region for which the diffraction efficiency is calculated

W_m : weight for the m-th region

η_{mjl} : diffraction efficiency for the j-th order diffraction light of the m-th region at the l-th wavelength .

Cancelled claims 30-31

32. (amended) A method for designing diffraction lenses, comprising:

an input step of entering lens design data;

a processing step of calculating optical properties and diffraction efficiencies of

the diffraction lens obtained on the basis of said design data;

an optimization step of optimizing the lens properties based on the result of the

processing step;

wherein the processing step of calculating the diffraction efficiencies is a method

for calculating diffraction efficiencies according to Claim 29.

33.   The method according to Claim 32, wherein said optimizing step optimizes aberration and diffraction efficiency.

Cancelled claim 34

35.   A computer–readable recording medium storing a computer–executable program for calculating diffraction efficiencies of a diffraction lens divided into a plurality of regions, each region comprising at least one grating ring,   wherein the program executes:

a first memory step of storing information about diffraction efficiencies of said regions;

a second memory step of storing information about weights corresponding to said regions;   and

a first processing step of retrieving information stored in said first and said second memory step, and calculating diffraction efficiencies of the entire diffraction lens using the formula

(1) $$E_j = \sum_{m=1}^{M} W_m \eta_{mj}$$

wherein:

j :   integer indicating the order of diffraction light

E_j : diffraction efficiency for j–th order diffraction light of the diffraction lens

M : positive integer (M > 1) indicating the number of regions for which the diffraction efficiency is calculated

m : index of the region for which the diffraction efficiency is calculated

η_{mj} : diffraction efficiency for the j–th order diffraction light of the m–th region (stored in the first memory step)

W_m : weight for the m–th region   (stored in the second memory step).

36.   The recording medium according to Claim 35, wherein the program further executes:

a third memory step of storing information about a relief cross–section shape of the diffraction lens;

a fourth memory step of storing information about a wavelength of a light source;

a fifth memory step of storing information about a refractive index of a material of the diffraction lens at said wavelength;

a second processing step of retrieving information stored in said third, fourth and fifth memory step, and calculating diffraction efficiencies of said regions of the diffraction lens;   and

a first repeating step of repeating said second processing step for a number of times that is equal to the number of said regions;

wherein the diffraction efficiencies η_{mj} stored in said first memory step are calculated using said third, fourth and fifth memory step, said second processing step, and said first repeating step.

37.   The recording medium according to Claim 35, wherein each grating ring of the diffraction lens corresponds to one of said regions.

38.   The recording medium according to Claim 36, wherein said second processing step includes a calculation using a Fourier transformation.

39.   The recording medium according to Claim 35, wherein the program further executes a calculating step of calculating the weights stored in said second memory step using information about the diffraction lens.

40.   The recording medium according to Claim 35, wherein the program further executes:

a sixth memory step of storing information about surface areas of said regions of the diffraction lens,   and

a third processing step of retrieving information stored in said sixth

memory step, and calculating weights using the formula

$$(2) \qquad W_m = \frac{S_m}{\sum_{i=1}^{M} S_i}$$

wherein:

S_m : surface area of the m-th region

W_m : weight of the m-th region

M : number of regions into which the lens is divided

m : index counting the regions into which the lens is divided

i : integer

wherein the weights corresponding to the regions stored in said second memory step are calculated using said sixth memory step and said third processing step.

41.   The recording medium according to Claim 35, wherein the program further executes:

a seventh memory step for storing information about radii of the grating rings of the diffraction lens;   and

a third processing step for retrieving information stored in said seventh memory step, and calculating weights using the formulas

$$(3) \qquad W_i = \frac{R_i^2}{R_M^2} \qquad \text{and}$$

(4) $$W_m = \frac{R_m^2 - R_{m-1}^2}{R_M^2} \quad (m > 1)$$

wherein:

R_m : m–th grating ring radius counted from the center of the lens

W_m : weight of the m–th grating ring

M : number of grating rings

m : index counting the grating rings from the center of the lens

wherein the weights corresponding to the regions stored in said second memory step are calculated using said seventh memory step and said third processing step.

42.   The recording medium according to Claim 35, wherein the program further executes:

        a seventh memory step of storing information about radii of the grating rings of the diffraction lens;

        an eighth memory step of storing information about an intensity distribution for a light beam that is incident on the diffraction lens;   and

        a third processing step of retrieving information stored in said seventh and eighth memory step and calculating the weights so that they are substantially proportional to the light intensity of the light that is incident on the corresponding grating ring of the diffraction lens;

        wherein the weights corresponding to the regions stored in said second memory step are calculated using said seventh and eighth memory step and said third processing step.

43.   The recording medium according to Claim 36, wherein the program further executes a calculating step of calculating the cross–section shape of the diffraction lens stored in the third memory step.

44.   The recording medium according to Claim 36, wherein the program further executes:

a ninth memory step of storing information about a relief profile design for the diffraction lens;

a tenth memory step of storing information about a processing bit that is used for cutting the diffraction lens or cutting a die for forming the diffraction lens;

a fourth processing step of retrieving information stored in said ninth and tenth memory step, and calculating a relief profile of a diffraction lens that was cut with the processing bit or a relief profile of a diffraction lens formed using a die that was cut with the processing bit;   and

a second repeating step of repeating said fourth processing step;

wherein the cross-section shape of the diffraction lens stored in said third memory step is calculated using said ninth and said tenth memory

step, said fourth processing step, and said second repeating step.

45.   The recording medium according to Claim 36, wherein the program further executes:

a ninth memory step of storing information about a relief profile design for the diffraction lens;

a tenth memory step of storing information about a processing bit that is used for cutting the diffraction lens or cutting a die for forming the diffraction lens;

an eleventh memory step of storing information about feed speed of said processing bit;

a fourth processing step of retrieving information stored in said ninth, tenth, and eleventh memory step, and calculating a relief profile of a diffraction lens that was cut with the processing bit or a relief profile of a diffraction lens formed using a die that was cut with the processing bit;   and

a second repeating step of repeating said fourth processing step;

wherein the cross-section shape of the diffraction lens stored in said third memory step is calculated using said ninth, tenth and eleventh memory step, said fourth processing step, and said second repeating step.

46.   A computer–readable recording medium storing a computer–executable program for calculating diffraction efficiencies of a diffraction lens divided into a plurality of regions, each region comprising at least one grating ring, the diffraction efficiencies corresponding to a plurality of wavelengths, wherein the program executes:

a first memory step of storing information about diffraction efficiencies of said regions at the plurality of wavelengths;

a second memory step of storing information about weights corresponding to said regions;

a third memory step of storing information about a relief cross–section shape of the diffraction lens;

a fourth memory step of storing information about the plurality of wavelengths;

a fifth memory step of storing information about refractive indices of a material of the diffraction lens at said wavelengths;

a fourth processing step of calculating a relief cross–section shape of the diffraction lens stored in said third memory step;

a second processing step of retrieving information stored in said third, fourth and fifth memory step, and calculating therefrom diffraction efficiencies of said regions at said plurality of wavelengths stored in said first memory step;

a third repeating step of repeating said second processing step for a number of times that is equal to the number of said wavelengths;

a fourth repeating step of repeating said third repeating step for a number of times that is equal to the number of said regions;   and

a first processing step of retrieving information stored in said first and said second memory step, and calculating diffraction efficiencies of the entire diffraction lens using the formula

(5) $$E_{jl} = \sum_{m=1}^{M} W_m \eta_{mjl}$$

wherein:

   j :   integer indicating the order of diffraction light

   l :   index of the wavelengths

   E_{jl} : diffraction efficiency for j–th order diffraction light of the diffraction lens at the l–th wavelength

   M : positive integer (M > 1) indicating the number of regions for which the diffraction efficiency is calculated

   m : index of the region for which the diffraction efficiency is calculated

   W_m : weight for the m–th region

   η_{mjl} : diffraction efficiency for the j–th order diffraction light of the m–th region at the l–th wavelength .

Cancelled claims 47-79